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June 1, 1992

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

HAND DELIVERED

Ms. Donna R. Searcy, Secretary
Federal Communications Commission
Washington, D.C. 20554

Re: Echo Group L.P.
Request for Pioneer's Preference
File No. PP-36,
ET Docket No. 92-100

Dear Ms. Searcy:

Submitted in connection with the above-referenced Request for Pioneer's Preference filed by Echo Group L.P. ("Echo") on July 30, 1991 is the enclosed original and five (5) copies of a Progress Report regarding the testing of Echo's proposed mobile data radio service ("MDRS") technology. Attached to the report is a separate package containing appendices to such report. **Pursuant to Section 0.459 of the Commission's rules, 47 C.F.R. § 0.459, Echo requests that the appendices be withheld from public inspection.** The appendices consist of technical data which would customarily be guarded from disclosure (but for the necessity to submit such test results to the Commission) in that they were prepared from tests conducted in part using systems licensed to third parties. These parties have requested that the confidentiality of such information be maintained.

The public will not be harmed by granting this request because the information contained in the report itself is sufficient to enable the public to comment on the tests. Any questions or communications should be addressed to the undersigned. Further, if this request for confidentiality is denied, please do not make the

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appendices to the report public prior to giving Echo the opportunity afforded under Section 0.459(g) to seek review of such denial.

Sincerely,

Jay L. Birnbaum
Counsel for Echo Group L.P.

Enclosures

cc: Parties in ET Docket No. 92-100

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Mobile Data Radio System Progress Report

By:
Bruce Lusignan
Chairman, TransTech International
Director, Communications Satellite Planning Center

1.0 Overview

Echo Group (ECHO) and TransTech International (TTI) have developed and tested a new digital packet radio system capable of providing more frequency efficient and cost efficient services than other systems currently offered or proposed. The system is targeted at short to medium length (10's to 100's of bytes) data messages. It is designed to handle bursty data efficiently using a patented protocol. (Bursty data is data which arises infrequently but requires a rapid response when it does arise.) Key to the system are low installation, operating and equipment costs for the base stations and low equipment and operating costs for the user terminals. Low base station costs allow rapid expansion of service, installation of more base stations to improve frequency reuse in urban areas, increased coverage in rural areas and reduced charges to users. Low-cost user terminals put the service within reach of a number of applications not served by more expensive systems such as point of sale terminals, delivery services, utility monitoring, etc. Echo believes the system is capable of supplying data services to the public at far lower costs than services offered by other carriers.

Nine US cellular carriers and IBM recently announced a unified approach to data services, targeting high data rate, high cost services to the user markets dominated by the largest corporate users. (Mobile Data Report, May 4, 1992) Echo, on the other hand, has requested the FCC to allocate a set of nationwide frequencies to allow competitive service offerings based on high efficiency and low service cost.

2.0 The History of Development of The Echo System

First prototypes of the Echo system were tested on the cellular band in San Diego under a license issued to Pac-Tel Cellular. These tests established the performance parameters for radio wave propagation in challenging terrain and high-density urban population centers. The ability of the data transceivers to receive and transmit signals in mobile applications and in fixed locations was tested. Signals were reliably received in a wide variety of buildings and installation sites within buildings, on the open freeways and in high use "canyons" and shadow areas of hills. (See Appendix I) Criteria were developed to relate measured coverage to projected coverage patterns calculated by computer programs using Longley-Rice propagation models, developed by the Bureau of Standards, and terrain data of the US. Geological Survey. (These techniques will allow a rapid deployment of nationwide services, providing wide area coverage with best placement of base stations.)

This phase also demonstrated the ability to offer service within the Cellular AMPS channel allocations without interfering with voice services. The patented frequency clearance technique was developed for Cellular Data Inc. (CDI) which has since carried out additional field tests with cellular carriers.

Also developed during this phase was the patented data protocol technique which allows a rapid response to bursty data originating from the user. This technique uses a single bit to be transmitted from a user unit indicating that it is ready to originate data transmission. The technique uses the lowest overhead possible to provide a quick response to user-originated traffic. Coupled with priority queuing and flexible incoming and outgoing data scheduling, the system has the least overhead and highest channel capacity attainable. The technique was developed and patented during this first phase and later perfected in low-cost base station hardware.

The second phase of development was done in conjunction with Domestic Automation Corporation (DAC) as a demonstration for Pacific Gas and Electric. This system, using the public utility band at 928-952 MHz, was demonstrated in San Rafael, California. A base station was installed in a hilly area and used to monitor user units attached to electric power equipment. User units were built and installed at power distribution transformers, customer-premise power panels and home power meters.

Three base stations were built for DAC and thirty-two radio units. An extra base station and extra user units were developed for Echo for testing and demonstrations at the TTI facilities in Mountain View, California. *

* Testing conducted pursuant to Experimental File No. 1375-EX-PL-90.

The San Rafael tests confirmed base station coverage patterns, providing coverage in clear areas up to five miles from the base site. (See Appendix II)

This phase also confirmed the engineering design of the user radios and the base stations. The prototype radios used mass production design procedures to allow low-cost manufacture on surface mount device (SMD) production lines. Automatic production line testing and minimum tuning for final operation keep radio cost well below similar products on the market ($85 is the projected user radio cost).

The base station design emphasized very low cost, ease of installation and reduction of "visual pollution" to allow acceptable installations in the cities. Equipment cost for the base station is about $5,000, less than one-tenth the cost of comparable facilities. The base station resides in a 2-1/2' by 1-1/2' utility cabinet that can be mounted outdoors near the single "broomstick" antenna it connects to. The "control center" is any IBM compatible P.C. that can be mounted up to 300 feet away from the antenna and connected by standard telephone wiring. The base station connects to leased line modems and/or to a packet network, depending on the application. This technique minimizes central facilities costs (including site rentals), allowing rapid expansion of services.

Since applying for a Pioneers Preference, Echo has demonstrated its system to cellular carriers and potential users. We have refined the techniques and approaches Echo plans to use in the frequency allocations we hope will be awarded by the FCC.

The recent decision by nine US cellular carriers and IBM to offer only a higher-cost, higher data rate (up to 19.2 kb/sec) system increases the importance of granting a nationwide frequency allocation to allow a competing service to be offered to users more interested in an efficient low-cost, lower data rate (2.4 to 9.6 kb/sec) system. To illustrate the potential of low cost, Section 4.0 outlines possible service offerings based on the Echo system.

3.0 Technical Summary

The Echo technology simplifies both base station and user radio design for low service cost and efficient use of the spectrum.

3.1 Modulation

Transmitter and receiver use minimum shift keying (MSK) to transmit 2.4 kb/sec data streams on 5 kHz spacing. The spectrum allocation is shown in Figure 1 overlaying a standard 30 kHz allocation. The spectrum is shown in Figure 2 contrasting with a typical AMPS cellular data channel. In each 50 kHz allocation requested in the MDRS filing, ten channels would be used; five outbound from base station to user units, five inbound from user units to base station.

The total frequency utilization is thus 24 kb/sec in a 50 kHz allocation, typical of efficient mobile radio systems when guard bands are accounted for. Rather than using one high data rate channel in the service, ten are used in order to have frequency-reuse within urban areas, to aggregate different user groups on different carriers to improve efficiency and to keep the user radios inexpensive by minimizing power required and speed of processing.

3.2 Frequency Reuse

The frequency reuse strategies are similar to those available to the mobile radio and cellular industries. Initially the systems will be installed with antennas on tall buildings in order to achieve a typical coverage range of three to four miles. About twenty base stations will cover a typical urban area. The ability to reuse the same channel in a distant cell depends on the application. For mobile users with omni-directional antennas, frequencies could be reused every five to seven cells. (This is better than normal cellular frequency planning because of the rugged error tolerance of the data system). For fixed applications, where installation of the radio avoids bad fading and in some cases even uses directional antennas, the radiation to distant base stations is reduced. For these applications a frequency can be reused every three cells with acceptable performance.

The allocated capacity is then reused three to four times for mobile users, and up to seven times for fixed applications.

The second phase of the proposed MDRS service will reduce base station antenna heights in crowded areas, reducing coverage and increasing reuse within the given urban area. This can be done until a coverage area of about 1-1/2 miles in radius is achieved; below that size irregular paths between building and multipath reflections cause cells to overlap and prevent further divisions. Typically a threefold increase in capacity can be achieved by reducing coverage areas. Such improved capacity is planned for expanded MDRS service.

In the calculation of service capacity (Section 4.0) a frequency reuse of five times is felt to be typical for Phase I systems in which taller antenna heights are used in order to rapidly obtain full area coverage. In Phase II a frequency reuse of fifteen times is expected to be achieved by lowering heights of antennas, sectoring (using directional antennas to cover smaller areas) and adding more stations. This heavy reuse factor is assisted by the tolerance to interference of the data check and repeat request technique.

3.3 Data Management

Echo and TTI have developed and patented a unique data management technique adapted to the wireless data environment. It achieves a ninety percent fill factor, is virtually error free and adjusts automatically to a variety of different applications. The protocol is transparent to other computer industry protocols, translating if necessary to the user's protocol when the data passes to the user equipment or is passed into the land-side network.

The data management hardware is illustrated in Figure 3. Outgoing data (DT's) requests for incoming data (DR's) and requests for user unit status (SR) are loaded in priority queues. The queue routine creates a series of packet transmissions from these series of data flow requirements according to the defined priority. Because the outgoing data stream is managed by the single processor, there is no inefficiency; time slots are allocated dynamically according to data priority.

All incoming data is also fully managed by the single processor. Data Request and Status Request commands order the user units to transmit in designated time allocations in the incoming data stream. Thus the incoming data stream is also allocated dynamically according to priority.

The efficiency is further illustrated by the data word formats, Figure 4. Data transmission (DT) is packet addressed to each user, specified by unique address and major class or "type". Data is transmitted variable in length specified on each transmission and containing a simple block code error check. This command does not require a user unit response on the incoming channel. It is used in circumstances where a later transmission will check the reception.

The status request command is broadcast to all user units. It causes them to transmit one bit only. It is transmitted at a time designated by the "delay" field and by each user unit's individual index number. The result is an incoming bit stream of one bit from each user indicating whether it requires a data transmission (1) or not (0).

The Data Request is a two-way transmission with a short packet to the user and a command to transmit a specified "length" of data back at a defined time "delay".

The incoming data path is fully defined by the base station queue routine. It is loaded according to the data request priorities and status request priorities to capacity without blockage.

Since the queue routine fully defines the incoming data stream dynamically, it can easily process the data flexibly. A "frame mask" is transferred to the receiving routine,telling it what every byte in the incoming data stream means. This is used to interpret the data and route it to the correct user output file.

Note that the base station hardware is byte synchronous on transmit and receive. A similar synchronous system in the user radios (locking to the base station transmission) makes a synchronous time slot system in the cell, eliminating the need for synchronizing overhead on the return path.

The time slot assignments and frame mask also eliminate the need for user ID. or addressing on the return link, again reducing overhead.

Figure 5 illustrates the one bit Status Request command. This is a hardware solution to the problem of random origination of data traffic from the user units. The "bursty traffic" problem normally requires multi-byte inquiries and responses from the base station, regular assignment of data slots that are infrequently used, or "random access" transmissions in which a user wanting service merely transmits hoping to find a clear space. For short message bursty traffic, other systems normally run at twenty percent to thirty percent of the channel capacity.

The status request (SR) command solves the problem by transmitting a broadcast request to all user units in the cell. If the users have data to transmit they send one bit set to "1"; if not they transmit one bit set to "0". Each user transmits on a different bit delay measured from the time of SR command reception. The result is a string of 1's and 0's representing incoming data needs. This string is analyzed by the base station firmware and a series of data requests (DR's) is generated to bring in the data. The hardware to generate the one-bit pulse and demodulation then is key to the technique. Figure 5 shows the discrete pulse as received at the base station. The two vertical bars show where one bit has been transmitted. The top curve shows the power received. The bottom curve shows about five consecutive traces where the alternate "1" and "0" traces are well separated where the bit is transmitted but random where only noise is incoming. The one bit transmission has a controlled rise and fall time to register a clean detected signal while maintaining good spectral use.

The normal use of the status request allows the data at the user units to be detected every several seconds using about ten percent of the incoming data channel. The desired latency time and percent overhead depends on the application. Normally the repetition rate of the status request will be varied according to the needs of users.

The instruction set is equipped with two status request commands to allow a "log-on" feature for infrequently used terminals. Once every half minute or so this log-on status request is sent. User units not already on the primary (SRa) index list, respond to the log-on (SRb) request. The base station then, through a DR command, logs them on to the primary (SRa) list. This allows the SRa list to be kept shorter when large numbers of users need to be activated only intermittently or are normally serviced by other cells.

The data flow is summarized in Figure 6. Normally about 25 to 100 bytes is the length of message sent in the DT or DR command. For most applications this represents the complete transaction. A credit check at a point of sale terminal, verification of delivery of a package delivery truck, dispatch information for taxis, burglar alarm status, E-mail messages, equipment status in a power grid, inventory information for a traveling sales representative, etc. fall within the 200 byte message length. For longer messages the software in the base station and user unit controllers divide the packets into shorter commands, verifying each subpacket's successful transmission before sending the next. For divided messages from the user unit to the base station, the transmitter status byte in the DR response packet is used to indicate to the base station that the user unit buffer has more data to send.

Under normal loading conditions, queue lengths less than ten messages, throughput in the MDRS system is under three seconds. This allows normal packet network protocols to operate without special timing.

3.4 Error Correction

The system uses a check sum to determine whether the signals are received correctly. The user units receive this and then respond to the DR command on the indicated time slot in the return channel. The error check in the return channel is tested in the base station. If the base station does not receive a valid response to its DR command, which could result from an error in either path, the DR command is recirculated to the outgoing command queue. A number of retries will be made depending on the user requirement; continued misses are logged into maintenance routines and "no answer" messages are reported to the user. This automatic retransmission request (ARQ) is the most effective way to provide error free data transmission (the error rate is actually about 10^{-14} depending on the length of the data field). Use of forward error correction (FEC) is impractical in the mobile radio environment, where errors typically occur in bursts taking out blocks of bits and making the FEC algorithms fail. The ARQ technique in most cases takes one or two percent overhead and occasionally requires a second transmission (about one to five percent of the time).

The DT command does not directly use an error correction check. This is available for systems that would process the data received before a confirmation is expected. In these applications either the user unit will originate a response through the SR command or the sender will follow the DT request with a DR command to confirm reception.

The SR commands, which result in a single bit response from each user unit, are sent every few seconds. An error in receiving or a weak transmission back to the base station will be detected as a low power response at the base station, not an incorrect "1" or "0". The base station detector hardware measures signal strength and frequency of the transmitted bit; both are reported to the data firmware. If successive responses to the SR commands show no response, the user unit is reported to the maintenance software. This feature allows the system to provide a continuous status record on each user unit if requested to do so.

The data to and from the base station from the land side is carried by standard nationwide packet network facilities and/or by private networks of major users. This is described more fully below.

3.5 Base Station Hardware

An important feature of the base station is its low cost and small size. It has three components: an antenna, an outdoor radio base unit and an indoor P.C. processor. Equipment cost for the base station with redundancy is about $5,000.

The antenna is selected to cover the desired geographic area, either a broomstick antenna for equal gain in all directions or one or more Yagi antennas for sectored area coverage. The antennas are slightly smaller than those used in the cellular band because of the higher frequency proposed for the MDRS system.

The outdoor radio unit is housed in a weatherproof container about 2-1/2' x 2-1/2' x 3/4'. It is mounted under the eaves near the antenna and connects to a nearby electric power outlet. The unit is smaller than many general utility boxes. The antennas also are inconspicuous and can be designed and painted to blend with the building decor. Visual acceptance is important in obtaining site locations in urban areas. The outdoor unit, its block diagrams and specifications are summarized in Figures 8, 9, 10 and 11.

The outdoor unit is connected by three twisted pair connections and spare ground wires to the indoor unit. The lines are driven differentially and terminated with line impedance's to allow transmission of data reliably up to 300 feet. Normal 24 gauge telephone wiring can be used to locate the indoor unit anywhere convenient within the building.

The base station indoor unit is a desk top computer and can be located anywhere where access and space can be obtained at low cost. It is operated unmanned. The computer display is normally used only for maintenance visits. The indoor unit consists of a single IBM compatible P.C. insert card that can be plugged into the card slot in the computer (similar to standard modem cards). Each card handles the data flow for one 2,400 b/sec channel. Three cards can be placed into one P.C.. The data handling at the level above the firmware described above is developed in C language using convenient communications software. The firmware handling the radio protocols are all done on the processor in the plug-in card.

Management and billing information is extracted by the P.C. software and transmitted independently into the packet network, addressed to the MDRS billing center and to the MDRS maintenance center in each major city. For larger users, location, status and usage information can be reported separately to other facilities anywhere in the nation through the packet network.

The base station for general purpose applications will deposit the messages into a general purpose packet-switch network using a modem card and X.25 protocols. The P.C. software generates the routing signals to move mobiles from one cell to another within the X.25 addressing schemes. For large users special software and separate modems will be added to route the data directly to their own private networks or to message centers in cities.

This flexibility allows the MDRS system to route messages cost effectively into the wired network or into special customer networks, saving the user extra land side charges.

3.6 User Radio Units

The main goal of the radio user unit design is to keep the cost low so that a wider range of applications can be served. Figure 13 is a drawing of the radios used in the field tests with PG&E. They are 4" x 6" x 1-1/4". They contain two cards, a radio card and a digital card and are designed to use an external battery and a small (approximately 3") stub antenna. This particular package was designed to mount in and control electric power equipment. About one-third of the digital card (Figure 14) and one-half of the radio's digital processor are specific to the user's application. In the PG&E application a general purpose protocol is programmed into the unit to converse with computers in the electric power control processor.

The entire radio, including the user specific hardware, has a manufactured cost in medium volume of $85, including SMD production line automatic testing and final tuning of three radio components. The advanced design of the radio section, transferring more responsibility for performance to special logic circuits, greatly reduces product cost. The proprietary gate array logic and simple firmware in the processor provides digital frequency locking and temperature compensation, amplitude adjustment, MSK demodulation, modulation error correction, bit edge detection and locking, frame synchronization, byte-to-8-bit conversion, single bit shape forming, clock off set adjust (to compensate for transmission delay between base and user unit), bit-check coding and decoding and several other "house keeping" functions. These replace many touchy analog circuits by a logic gate and a simple processor costing less than $7.

The rugged packaging for the power utility industry will also be used for many other data services. Figure 15 shows a delivery van radio packaging concept developed for one potential user. The external case has been modified to include seven function keys and two indicator lights to be programmed for the user's employee procedures. A holder and bottom connector is added to interface with a pocket computer. The delivery service employee enters information into the pocket computer while visiting the customer and then replaces the computer in the holder. Information is read out and is ready automatically for transmission through the radio to the network. The antenna can be connected to a printed circuit loop on the roof or in most areas a stub antenna on the radio itself is perfectly adequate. A general purpose RS232 port has been kept for future equipment if necessary.

The system shown in Figure 15 still has a product cost of $90, (no circuitry has been added over the basic radio). The available digital capacity in the radio has been customized to an application category. The application illustrates just one of about seven packaging alternatives Echo plans to offer with its MDRS system. A simpler delivery service option will use the existing on/off lights, eliminate the general purpose RS232 port, add a short alphanumeric display and light-pen bar-code reader. Bar-codes printed on the radio contain common responses and bar-codes on the delivery papers contain the management information required to be transmitted to the tracking centers.

Simple packaging interfaces will be developed for point-of-sale terminals, security monitoring equipment, car alarms, E-mail "mail boxes", area monitoring networks (similar to the PG&E system) for water and gas grids, air quality monitors, etc. Many applications can use the current basic design with the battery connection and RS232 port. Others will benefit by programming the available capacity of the radio's processor to run the external sensor such as a light pen, LCD display or credit card reader.

Within eighteen months, a smaller packaging version is planned for laptop computers and two-way pagers. The radio's area will be shrunk using a TTI proprietary switched capacitor receiver already developed and tested. Half the area of the digital board will be eliminated for the paging and computer messaging functions. TTI has also developed a proprietary antenna design integrating the antenna into components available on all laptop and notebook computers.

While Echo feels personal communications devices (pocket radios) represent an important and growing market, it also recognizes that there is a very large market for the more rugged vehicle radios, business machines and equipment monitors. The base stations are designed to handle the full range of user devices.

4.0 Possible Service Offerings

The MDRS system has the flexibility to combine a wide range of services within the same base station channels. Messages are addressed to individual units with variable data length to suit the applications. The use of status checks (SR) can be varied according to user category. The use of fully acknowledged (DR) commands or one way (DT) commands can be varied as needed to suit the application. For general applications the base station processor connects to the general X.25 packet network using normal router "roaming" features when a unit moves out of one coverage pattern into another. For special large user applications, a leased line to the base station from a central facility or a private network deliver the data to the users' network most efficiently.

Each base station controller can route the data for up to three 2.4 k/sec data channels to the packet network or to several private networks. The queuing system processing the three priority levels of DR and DT commands and status commands ensure that the mix of service runs with minimum queuing delay and no blockage even though the traffic is mixed.

To estimate the service capacity of the MDRS system, we can use a typical Metropolitan Statistical Area (MSA) and then compare the capacity of the MDRS channels with the requirements of several typical applications. The typical MSA is assumed to be about the size of the San Francisco Bay Area or the Los Angeles Basin - about twenty base stations would cover the area. Five channels would be used in each direction, one channel to a base station, with a five-cell reuse pattern typically. The area would then support about twenty channels of 2.4 kb/sec data outgoing and incoming.

The MDRS system, because of its low cost base stations, is able to add additional base stations easily as traffic grows. The capacity will be increased through cell division as traffic warrants. This will increase the MSA capacity by up to three times, sixty channels of 2.4 kb/sec data outgoing and incoming.

The capacity of systems varies with the message service provided. Because the MDRS system adjusts its data formats to match the service needs, each service will have a different number of users that can be accommodated. Below a "typical" characteristic of a user group will be assumed and a number of users calculated assuming one-fourth to one-eighth of the MDRS capacity is allocated to that application. Other assumed characteristics can be substituted for the ones stated to find other service characteristics.

4.1 Delivery Service Verification

A truck driver delivers a parcel to a customer and enters the transaction into the radio through a bar-code read pen. The radio reports the stored message 100 bytes long back to the base station. A service request every minute is adequate since the stored message is automatically held until the DR request is received. One truck delivers 100 packages a day through the eight-hour business day. How many trucks N can be served with one-fourth of the day-time capacity?

108 bytes are transmitted each transaction. Each truck generates 100 messages in the eight-hour day. In eight hours 86,400 bits are generated per truck.

In the first phase, the MSA would have twenty 2.4 kb/sec channels covering the urban area. At eighty percent efficiency, including inquiry (SR) commands at low loading to avoid delay, the number of trucks served in the MSA is equal to:

1/4 (capacity) x 20 (cells) x 2,400 (data rate) x .80 (efficiency) x 8 (hours) x 3,600 (sec/hr) = N (trucks) x 86,400 (bits/day)

N = 3,200 trucks;
Delivery Confirmations = 320,000 per eight-hour day

The status inquiry is sent every sixty seconds to one-tenth of the trucks in each cell (nominally the number would be one-twentieth but transition between cells and distribution would increase the number). The response to each SR inquiry would be 320 bits long on the incoming channel. Transmitted each minute, this would amount to 0.2% of the incoming data stream. It is included in the twenty percent overhead assumption. The outgoing channel is loaded less than one-tenth as much as the incoming channel. Each DR command uses 8 bytes outgoing to bring in 108 bytes of message.

4.2 Dispatch Service

A dispatch service sends 100 byte messages to vehicles, i.e., taxis, and tracks them by using SR to locate the cells they are in every ten seconds. A 300 byte message (about two lines of type) is sent to them every ten minutes during the eight-hour day, forty-eight messages each 1,600 bits long; each taxi receives 76,800 bits a day.

One quarter of the MRDS system in the urban area would supply this service to N taxis:

$$1/4 \times 20 \times 2{,}400 \times .80 \times 8 \times 3{,}600 = N \times 76{,}800$$

N = 3,600 Taxis

Dispatch Messages = 172,800 per eight-hour day

One-tenth of these taxis would be logged into each cell making 360 bits in response to the SR command every ten seconds. This is 1.5% of the return channel. This is included in the overhead assumed to be twenty percent. The SR command transmission is less than .15% of the outgoing channel.

Note that dispatch services are a load primarily to the outgoing channel (messages to the taxis) while delivery services send messages back to the land line side. While the above assumptions assume one-fourth of the capacity for each service, in actuality both services would use the same two-way channel; one using primarily outgoing, the other primarily incoming.

4.3 Point-of-Sale Terminals

Point of sale terminals transmit about 100 bytes and receive confirmation information typically about 50 bytes. They need to respond in about four seconds to be significantly faster than today's point of sale terminals connected to dialed phone lines.

Assuming each terminal originates a transaction every ten minutes during an eight-hour business day, the number of terminals in the MSA that would use one-quarter of the incoming data channel is:

N = 7,200 point of sale terminals

Credit Checks = 345,600 per eight-hour day

The point of sale terminals are fixed-location applications so the SR requests are divided evenly among the twenty cells. The SR functions every four seconds, using less than four percent of the incoming channel. Total use of the outgoing channel is about one-half of the incoming channel.

4.4 Burglar Alarm Monitoring

A base station sends an SR command to the alarm monitoring system every five seconds. Occasionally, typically once every hour or when a break-in occurs, a system message of twenty bytes is retrieved. In this application the one-bit monitoring responses to the SR command will set the limit to system capacity.

One-eighth of the system capacity in the MSA will amount to:

$$1/8 \times 20 \times 2{,}400 \times .80 \times 10 \text{ seconds} = N$$

Burglar Alarms Monitored = 48,000

Check of status every 10 sec.
Message when needed

4.5 Acknowledgment Paging Service

One application of importance is paging, in which a phone number and/or simple instructions are sent to a pocket pager. The transmission is acknowledged by the response on the DR command. The paging message is typically twenty bytes (160 bits) long, the acknowledgment message is about eight bytes. It is assumed that the average pager will receive four such messages per eight-hour day, i.e., 640 bits. To use one-eighth of the capacity in the urban area (MSA) will serve N pagers:

$$1/8 \times 20 \times 2{,}400 \times .80 \times 8 \times 3{,}600 = N \times 640$$

N = 216,000 pagers

Pages Sent = 864,000 per eight-hour day

Again the SR command will be used every ten minutes to keep a running table of which pager is in which cell. Each cell will then generate about one-tenth of the pagers' one-bit response, 21,600 bits of response to the SR transmission, every five minutes. This amounts to about 2.5% of the incoming capacity. The response to the paging transmission itself occupies about five percent of each incoming channel.

The outgoing channel capacity (1/8 or 12.5%) is nearly balanced by the shorter response message and the SR response used to keep track of the pager's cell location.

4.6 Electronic Mail

Alphanumeric paging is not included above. It fits more generally into the category of E-mail. An E-mail message is transmitted to a pocket or notebook computer for later retrieval and display. A typical "letter" is assumed to be about ten pages long, about 1,000 bytes if coded in ASCI. Most "letters" would be outgoing to the user units. Perhaps half as many messages would be incoming. Each E-mail box receives five letters per sixteen hour day, or 40,000 bits, if one-eighth of the capacity were allocated to the E-mail service. The number of E-mail boxes N would be:

$$1/8 \times 20 \times 2{,}400 \times .80 \times 16 \times 3{,}600 = N \times 40{,}000$$

<u>N = 6,912 E-mail boxes</u>

<u>10-line letters = 34,560 per 16-hour day</u>

The E-mail boxes would be tracked like the pagers, using a small fraction of the incoming channel capacity.

The table on the following page summarizes the services that could be carried by the 5-channel system in the twenty cell MSA. *

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* Sections 4.1 - 4.5 are illustrative and not intended to be restrictive of the wide variety of services for which the system is designed, such as emergency radio location and tracking services, medical and environmental emergency services, services for the handicapped, and facility monitoring services (<u>e.g.</u>, electrical, heating or air conditioning systems).

Service	Number of Users	Number of Messages Per Day	Capacity In	Out
Delivery	3,200 Trucks	320,000 Confirms	1/4	--
Dispatch	3,600 Taxis	172,800 Dispatches	--	1/4
Point-Of-Sale	7,200 Terminals	345,600 Credit Checks	1/4	1/8
Burglar Alarm	48,000 Alarms	5 Second Checks	1/8	--
Pagers	216,000 Pagers	864,000 Pages	1/8	1/16
E-Mail	6,912 Boxes	34,560 Letters	1/16	1/8
Approximate Total:			81%+	55%+

Fractions of total capacity have been assumed to illustrate that the service does combines multiple users on a two-way service. Adjusting data flow automatically according to the priority of service.

This table is for the Phase I system, i.e., twenty cells covering the Metropolitan Statistical Area (MSA). In Phase II subdividing the cells will result in approximately a threefold increase in system capacity.

The capacity is far more than other systems using 25,000 Hz allocations. The advantage comes from the cellular reuse strategies, the elimination of burdensome protocol overheads for transmission of data through radio mediums and strategic use of the one-bit SR command to generate a service response time adjusted to the type of service.

A short comment can be made on the potential cost for the message service provided. This only sets limits in order to illustrate that the service can be viable in today's competitive markets. The check merely assumes that the capital investment in the Phase I MSA can be recovered in two years if a per-message price of $0.002 is charged for the expected traffic. The system capacity is about 1.8 million messages per day. With 250 working days per year, the annual capacity will be 450 million messages per year.

If the first two years runs at one-fourth of this capacity, the investment would have to be recovered from charges on 225 million messages.

The capital investment is approximately $400,000 in the MSA. This includes $20,000 per station conservatively to account for space rental installation, and service costs over the two year period.

With these two simplified assumptions, the per message cost for break even would be less than 0.2 cents per message. This is far below the current rates. It illustrates both the viability of the service economically and the importance to the public for the FCC to approve the petition and let Echo bring this competitive system to market.

5.0 Conclusions

The Echo proposal represents a dramatic advance in radio technology services, bringing technologies developed by an experienced pioneering engineer in the industry.

Continued developments in the technology continues at Stanford's Center for Telecommunications. The author will draw from the continuing advances to bring improvements to the service.

Respectively Submitted;

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Figure 1

Frequency Use with 5 KHz Separation

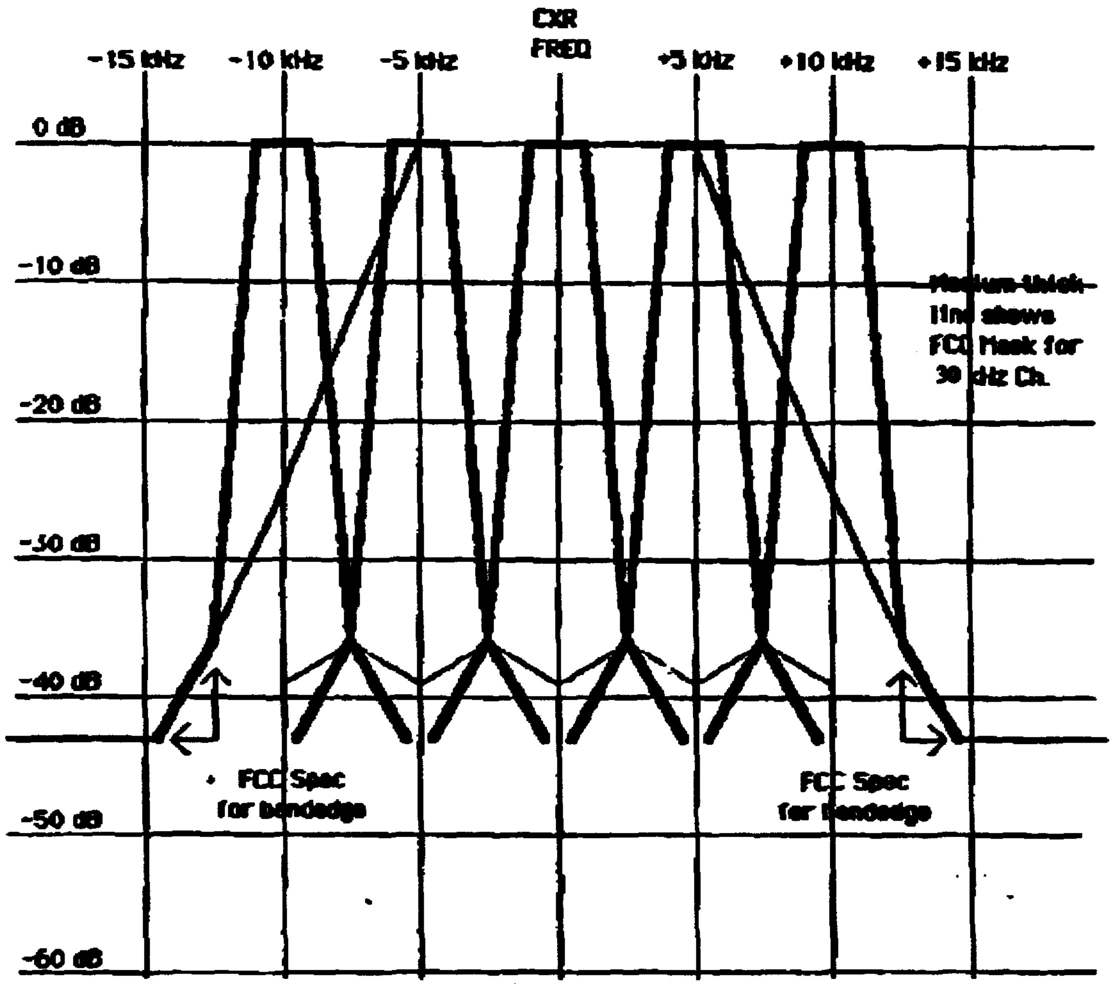
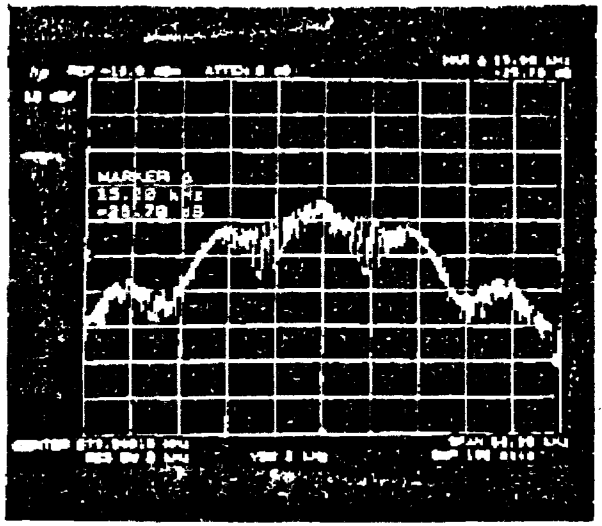
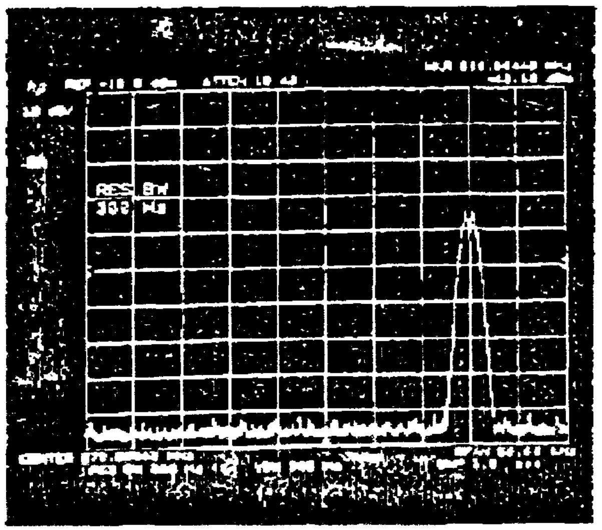


Figure 2

Comparison of Spectra of Voice and Data Services



Cellular Radio Channel



Packet Data Channel

Figure 3

Base Station Management of Outgoing and Incoming Data Flow